CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

STCW 78 as amended MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-32 - APPLIED HEAT

MONDAY, 16 OCTOBER 2017

1315 - 1615 hrs

Examination paper inserts:

Worksheet Q4 - Specific Enthalpy - Specific Entropy Chart for Steam

Notes for the guidance of candidates:

1. Non-programmable calculators may be used. 2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Materials to be supplied by examination centres:

Candidate's examination workbook Graph paper Thermodynamic and Transport Properties of Fluids (5th Edition) Arranged by Y.R. Mayhew and C.F.C. Rogers

APPLIED HEAT

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. Ethane, of volume 0.04 m^3, expands isentropically from a pressure and temperature of 6.9 bar, 260°C respectively, to 1.05 bar and 107°C.
The ethane is then recompressed to the original volume according to the law $pV^{1.4}$ = constant.

   (a) Calculate EACH of the following:

      (i) the temperature after recompression; (4)

      (ii) the net work transfer; (4)

      (iii) the net heat transfer; (3)

      (iv) the total change in entropy. (3)

   (b) Sketch the sequence of processes on a Temperature-specific entropy diagram. (2)

   Note: for ethane R = 277 J/kgK, c_v = 1265 J/kgK and γ = 1.219

2. The air standard efficiency of an Otto cycle is 68.53% and the indicated mean effective pressure is 5 bar.

   The minimum pressure and temperature in the cycle are 1.05 bar and 30°C respectively.

   (a) Sketch the cycle on pressure-Volume and Temperature-specific entropy diagrams. (2)

   (b) Calculate EACH of the following:

      (i) the volume compression ratio; (2)

      (ii) the specific work output; (4)

      (iii) the maximum cycle temperature; (6)

      (iv) the maximum cycle pressure. (2)

   Note: for air, γ= 1.4 and c_v= 718 J/kgK

3. A pure hydrocarbon fuel is completely burned in air.

The volumetric analysis of the dry exhaust gas gives 10.5% CO_2, 7.4% O_2, and 82.1% N_2.

Calculate EACH of the following:

(a) the percentage mass analysis of the fuel; (8)

(b) the air to fuel ratio by mass; (4)

(c) the gravimetric analysis of the total exhaust gas. (4)

Note: atomic mass relationships H =1, C = 12, O = 16, N = 14.
air contains 21% oxygen by volume.

4. A steam turbine plant producing 22 MW expands steam in two stages with reheat between the stages.

The first stage expands the steam from a pressure and temperature of 60 bar and 540°C respectively to a pressure of 5 bar, at which point, the specific entropy of the steam has increased by 2.15%.

The steam is then reheated at constant pressure to 470°C.

In the second stage, the steam expands to a condenser pressure of 0.05 bar and the specific entropy increases by 2.5%.

The feed water leaves the condenser at a temperature of 28°C.

The feed pump work cannot be ignored.

(a) Draw the expansion and reheat processes on Worksheet Q4. (4)

(b) Sketch the cycle on a Temperature-specific entropy diagram. (2)

(c) Using Worksheet Q4 determine EACH of the following:

(i) the mass flow rate of steam in tonne per hour; (5)

(ii) the specific steam consumption; (2)

(iii) the thermal efficiency of the cycle. (3)

5. The first stage of an impulse turbine is velocity compounded with two rows of moving blades. The isentropic enthalpy drop in the nozzles is 373.56 kJ/kg and the isentropic efficiency is 90%.

The steam leaves the nozzles at an angle of 30° to the plane of blade rotation and the mean blade speed is 200 m/s.

The first row of moving blades and the fixed blades are symmetrical.

The exit angle on the second row of moving blades is designed such that the absolute velocity of the steam at stage exit is in the axial direction.

A blade velocity coefficient of 0.9 may be assumed for all the blade rows.

(a) Draw the steam velocity vector diagram to a scale of 1 mm = 5 m/s (6)

(b) Determine EACH of the following:

(i) the blade angles for each row of moving blades; (2)

(ii) the blade angle for the fixed blades; (2)

(iii) the diagram power output for 1 kg/s of steam flow; (3)

(iv) the axial thrust for 1 kg/s of steam flow. (3)

6. A vapour compression refrigeration plant uses R134a and operates between saturation temperatures of -20°C and 40°C.

The refrigerant leaves the evaporator at -10°C and leaves the compressor at 60°C.

The heat removed in the condenser is 199.63 kJ/kg of refrigerant flowing and the cooling load is 60 MJ/hour.

(a) Sketch the cycle on Pressure-specific enthalpy and Temperature-specific entropy diagrams. (4)

(b) Calculate EACH of the following:

(i) the degree of undercooling in the condenser; (4)

(ii) the mass flow rate of <u>liquid</u> refrigerant entering the evaporator; (6)

(iii) the coefficient of performance. (2)

7. A steel pipe has a bore of 150 mm, a wall thickness of 10 mm and carries dry saturated steam at 12 bar.

It is covered with a 40 mm thick layer of moulded insulation which in turn is covered with a 60 mm layer of felt with an outer surface temperature of 25°C.

A change in regulations requires the felt to be replaced with a polystyrene material which cannot be used above 95°C.

The heat transfer rate and outer surface temperature are required to remain unchanged.

Calculate EACH of the following:

(a) the rate of heat loss per unit length of pipe; (7)

(b) the temperature at the moulded insulation/felt interface; (2)

(c) the thickness of the polystyrene if the moulded layer is undisturbed. (7)

Note: inner heat transfer coefficient = 550 W/m^{2}K
thermal conductivity of steel may be ignored
thermal conductivity of the moulded insulation = 0.07 W/mK
thermal conductivity of the felt = 0.1 W/mK
thermal conductivity of the polystyrene = 0.09 W/mK

8. In a two stage single acting reciprocating compressor, air is compressed from suction conditions of 0.9 bar 20°C to a delivery pressure of 12 bar.

The second stage entry conditions are 3 bar and 35°C.

The low pressure cylinder has a bore of 300 mm, a stroke of 150 mm and a clearance volume of 2.5% of the swept volume.

The index of expansion and compression in both stages is 1.25.
The compressor speed is 300 rev/min.

(a) Sketch the cycle on a pressure-Volume diagram. (2)

(b) Calculate EACH of the following:

(i) the free air delivered per hour at conditions of 1 bar and 0°C; (6)

(ii) the indicated power required to drive the compressor. (8)

Note: for air R = 287 J/kgK and c_p = 1005 J/kgK

9. A pump delivers fresh water at the rate of 32 tonne/hour. The delivery pipe is 90 mm bore. Suction is from a tank which is 0.9 m below the pump and delivery is to a tank which is 19.5 m above the pump. The discharge pipe has a total length of 25 m and has a friction factor coefficient of 0.01.

The efficiency of the pump is 75%.

Friction losses and velocity in the suction pipe can be neglected.

Calculate EACH of the following:

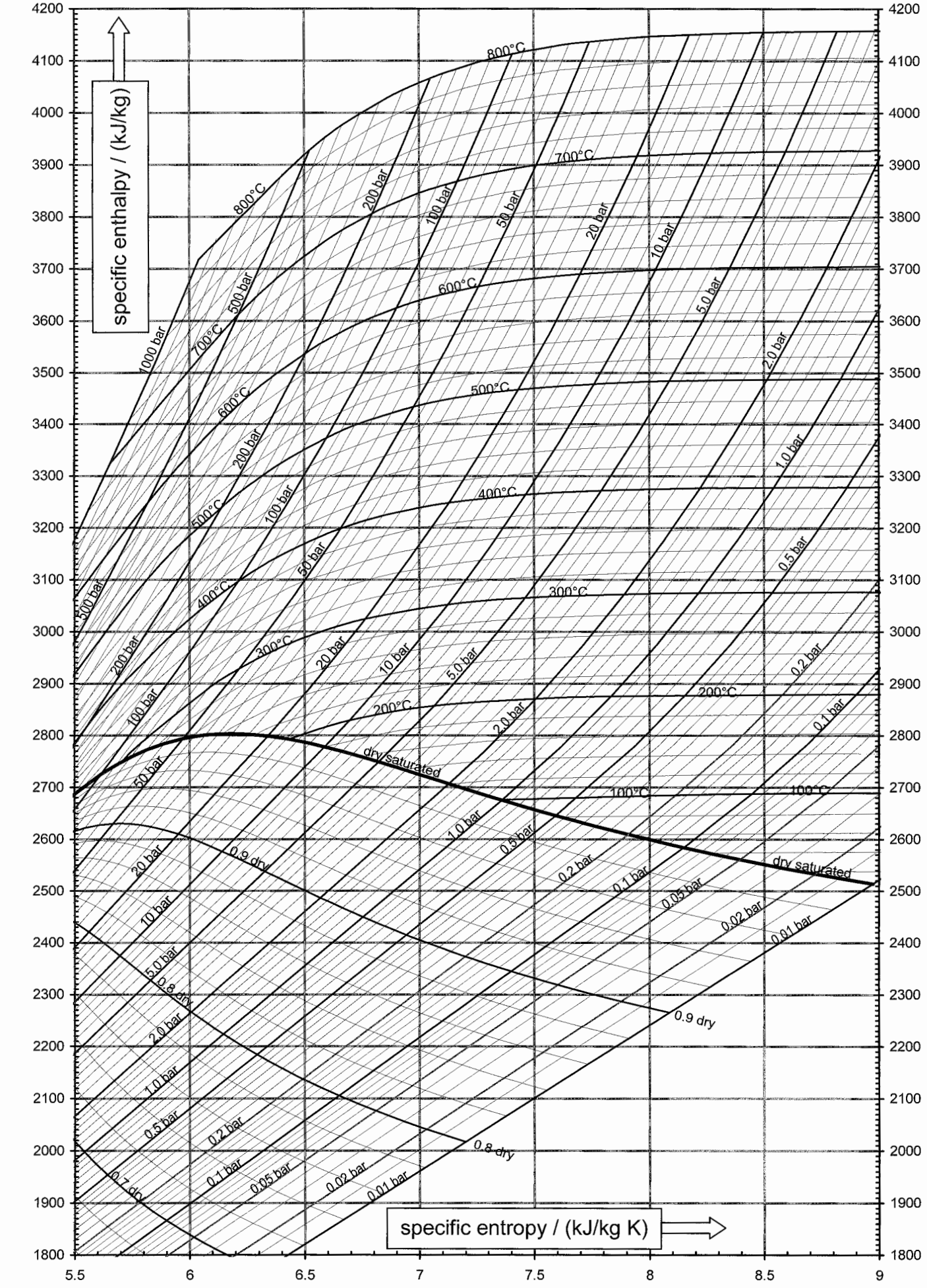
(a) the total manometric head in the system; (12)

(b) the input power of the pump. (4)

(This worksheet must be returned with your answer book)

Enthalpy Entropy Chart for Steam

(prepared at Glasgow College of Nautical Studies using data from NEL Steam Tables 1964 and other formulations: for exercises only)



Candidate's Name ..... Examination Centre .....